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SPECIFICATION

MANUFACTURING PROCESS OF STAINLESS STEEL PRODUCTS BY NITROGEN ABSORPTION TREATMENT AND STAINLESS STEEL PRODUCTS THEREBY OBTAINED

Technical Field

This invention relates to a manufacturing process of a stainless steel product by nitrogen absorption treatment and to a stainless steel product thereby obtained. More particularly, this invention relates to a manufacturing process of a stainless steel product by nitrogen absorption treatment, which can decrease production cost of austenitic stainless steel which is considered to be difficult to process, and can manufacture a stainless steel product having fully satisfactory properties in both strength and corrosion resistance, and to a stainless steel product thereby obtained.

Background Art

Austenitic stainless steel is a material which is difficult to process and its difficulty to work into a desired shape raises its production cost. As austenitic stainless steel is outstanding in both corrosion resistance and strength, it is desired that its products having desired shapes, including even complicated ones, be supplied at a low cost.

In the field of powder metallurgy, attempts have been made to have nitrogen absorbed at the time of sintering, but as large-scaled equipment is required for the manufacture of molded products by a method of powder metallurgy, the products which can be thereby manufactured are limited in size

ATTACHMENT A

and shape. Moreover, products made by a method of powder metallurgy have numerous holes known as pores, and they affect the mechanical properties of the products and make their mechanical reliability questionable.

No nitrogen absorption treatment has been adopted for bulk materials made by melting. The reason is that it has been common knowledge that if a metallic material is held in a nitrogen atmosphere at a high temperature for a long time, a microstructure is coarsened and mechanical properties are seriously lowered. In other words, a lowering in the mechanical reliability of bulk materials thus produced has been strongly feared.

This invention has been made under such circumstances and has as an object to provide a method of manufacturing a stainless steel product by nitrogen absorption treatment, which can decrease production cost of austenitic stainless steel which is considered to be difficult to process, and can manufacture a stainless steel product having fully satisfactory properties regarding both strength and corrosion resistance, and to provide a stainless steel product thereby obtained.

Disclosure of the Invention

In order to attain the above object, this invention provides a manufacturing process of a stainless steel product by nitrogen absorption treatment, characterized by bringing a bulk product of ferritic stainless steel, which is made by melting, forming and machining into a desired shape, into contact with an inert gas containing nitrogen at or above 800°C to austenitize the product completely, or to austenitize it partially and form a two-phase structure composed of ferrite and austenite (claim 1).

This invention also provides a stainless steel product characterized by having a completely austenitic structure which is formed by adding nitrogen through contact with an inert gas containing nitrogen, to a bulk product of ferritic stainless steel which is made by melting, forming and machining into a desired shape (claim 2).

Moreover, this invention provides a stainless steel product characterized by having a two-phase structure of ferrite and austenite which is formed by adding nitrogen through contact with an inert gas containing nitrogen, to a bulk product of ferritic stainless steel which is made by melting, forming and machining into a desired shape, so as to austenitize it partially (claim 3).

The manufacturing process of a stainless steel product by nitrogen absorption treatment according to this invention and the stainless steel products thereby obtained will now be described in further detail with reference to examples.

Brief Description of the Drawings

Fig. 1 is a photograph in place of a drawing, showing an ingot of ferritic stainless steel (Fe – 24 mass % Cr – 2 mass % Mo) made by melting in a vacuum arc melting furnace, and weighing 3.5 kg.

Fig. 2 is a photograph in place of a drawing, showing a round rod formed by hot and cold forging from the ingot shown in Fig. 1.

Fig. 3 is a photograph in place of a drawing, showing a plate formed by hot and cold forging from the ingot shown in Fig. 1.

Fig. 4 is a plan view of a round shape specimen for a tensile test

formed from the round rod shown in Fig. 2.

Figs. 5(a) and (b) show X-ray diffraction patterns of a test specimen subjected to nitrogen absorption treatment and a material equivalent to the test specimen, but not subjected to nitrogen absorption treatment, respectively.

Fig. 6 is a correlation diagram showing balance between strength and ductility of the test specimen, an existing alloy and the equivalent material not subjected to nitrogen absorption treatment.

Figs. 7(a), (b), (c) and (d) are polarization curves showing results of polarization tests conducted by immersing the test specimen, 316L stainless steel and the material equivalent to the test specimen but not subjected to nitrogen absorption treatment in a 0.9% NaCl solution, a PBS(-) solution, a Hanks' solution and an Eagle's MEM solution, respectively, and evaluating them for corrosion resistance.

Figs. 8(a) and (b) are optical micrographs showing surfaces of the test specimen and 316L stainless steel, respectively, as observed after the polarization test in the Eagle's MEM solution.

Best Mode of Carrying Out the Invention

According to a method of this invention of manufacturing a stainless steel product by nitrogen absorption treatment, a bulk product of ferritic stainless steel made by melting, forming and machining into a desired shape is brought into contact with an inert gas containing nitrogen at or above 800°C, so that it may be austenitized completely, or may be austenitized partially to have a two-phase structure formed from ferrite and austenite. A technique of bringing a bulk product having a desired shape into contact with an inert gas

containing nitrogen at or above 800°C belongs to a nitrogen absorption treatment classified as a solid-phase absorption method. Nitrogen is added to the whole product or a part thereof by heating it to or above 800°C in an inert gas atmosphere containing nitrogen. The method of this invention of manufacturing a stainless steel product by nitrogen absorption treatment makes it possible to obtain a product having a desired shape easily, since the product to which nitrogen is added is made of ferritic stainless steel which is easier to work than austenitic stainless steel. The scale of equipment in the powder metallurgy method, limits to shaping and mechanical reliability of products is dissolved.

The stainless steel product of this invention which can be obtained as described is completely austenitized, or is partially austenitized and has a two-phase structure formed from ferrite and austenite. Therefore, the stainless steel product of this invention is outstanding in both corrosion resistance and strength and is advantageously an inexpensive product, since its cost of processing is low, even if it may have a complicated shape. The addition of at least about 0.5% by mass of nitrogen to a bulk product of ferritic stainless steel is sufficient for achieving the results as mentioned above.

Example

An ingot of ferritic stainless steel (Fe – 24 mass % Cr – 2 mass % Mo) weighing 3.5 kg, as shown in Fig. 1, was made by melting in a vacuum arc melting furnace. The ingot was cut into four blocks each of which measures 25 mm square by 110 mm, and the blocks were hot-forged at 1100°C and cold-forged at ambient temperature into a round bar with 9 mm in diameter by

90 mm and a plate measuring 15 mm square by 1.5 mm in thickness, as shown in Figs. 2 and 3, respectively. A round shape tensile test specimen with a planar shape as shown in Fig. 4 was formed by machining the round bar shown in Fig. 2. These two kinds of test specimens were given nitrogen absorption treatment by a nitrogen absorption furnace.

Each test specimen was placed on a mesh board of SUS304 stainless steel, degreased and cleansed with acetone, and inserted in a nitrogen absorption portion of the nitrogen absorption furnace. The furnace was evacuated by a rotary pump until 2 Pa. Then, an inert gas containing nitrogen was introduced into the nitrogen absorption portion at a rate of two liters per minute, the nitrogen absorption portion was heated from room temperature to 1200°C at a rate of 5°C per minute and the test specimen was kept in contact with nitrogen at 1200°C for 24 hours.

After the nitrogen absorption treatment described above, the test specimen was quenched in iced water from 1200°C. After removal of scale from a surface by polishing, a microstructure was examined by using an X-ray diffractometer. A CuKα tube was used for X-ray diffraction and $2\theta/\theta$ was varied from 40 to 90 degrees at a rate of one degree per minute. The X-ray diffraction pattern as obtained is shown in Fig. 5(a). For comparison, Fig. 5(b) shows the X-ray diffraction pattern of a material equivalent to the test specimen, but not given nitrogen absorption treatment. As is obvious from comparison of Figs. 5(a) and (b), the test specimen given nitrogen absorption treatment was made of perfectly austenitic stainless steel. The amount of nitrogen addition was about 0.9% by mass.

Then, a tensile test was conducted on the test specimen by using an

Instron-type testing machine with a capacity of 100 kN at a crosshead speed of 0.5 mm per minute. Fig. 6 shows balance found between strength and ductility of the test specimen which had been given nitrogen absorption treatment, of the material equivalent to the test specimen which had not been given nitrogen absorption treatment and of a conventional alloy. As is clear from Fig. 6, the nitrogen absorption treatment realized a better balance between strength and ductility as compared with the conventional alloy and the material equivalent to the test specimen which had not been given nitrogen absorption treatment. The effectiveness of nitrogen absorption treatment was thus confirmed.

The test specimen was also evaluated for corrosion resistance.

The test specimen, 316L stainless steel and material equivalent to the test specimen which had not been given nitrogen absorption treatment were polarized in a 0.9% NaCl solution, a PBS(-) solution, a Hanks' solution and an Eagle's MEM solution which had been prepared at 37°C and deaerated with bubbling nitrogen gas. Figs. 7(a) to (d) are the polarization curves obtained by polarization tests conducted for evaluation on corrosion resistance. As is confirmed by Figs. 7(a) to (d), the test specimen showed higher corrosion resistance in all of the test solutions than the 316L stainless steel and the material equivalent to the test specimen not given nitrogen absorption treatment, and it did not have any pitting corrosion, as is obvious from Fig. 8(a). Pitting corrosion was found in 316L stainless steel, as shown in Fig. 8(b).

The method of this invention of manufacturing a stainless steel product by nitrogen absorption treatment and the stainless steel product thereby

obtained overcome the difficulty in processing austenitic stainless steel and make it possible for even a product having a complicated shape to be obtained at a low cost and have satisfactorily high levels of strength and corrosion resistance.

This invention is, of course, not limited by the mode or example as described above. It is needless to say that variations or modifications may be made in details including the composition of stainless steel, the shape and size of the product and the conditions of nitrogen absorption treatment.

Industrial Applicability

As is obvious from the detailed description above, this invention provides a stainless steel product formed from austenitic stainless steel which is considered to be difficult to process, has a desired shape, can be processed at a satisfactorily low production cost and has fully satisfactory properties with regard to both strength and corrosion resistance, and a method of manufacturing the same.

CLAIMS

1. A manufacturing process of a stainless steel product by nitrogen absorption treatment, comprising the steps of bringing a bulk product of ferritic stainless steel made by melting, forming and machining into a desired shape, into contact with an inert gas containing nitrogen at or above 800°C, and austenitizing the product completely, or austenitizing the product partially to form a two-phase structure composed of ferrite and austenite.

2. A stainless steel product having a completely austenitic structure formed by adding nitrogen through contact with an inert gas containing nitrogen, to a bulk product of ferritic stainless steel made by melting, forming and machining into a desired shape.

3. A stainless steel product having a two-phase structure composed of ferrite and austenite, which is produced by adding nitrogen through contact with an inert gas containing nitrogen to a bulk product of ferritic stainless steel made by melting, forming and machining into a desired shape so as to austenitize the product partially.

(Amendment)

Disclosure of the Invention

In order to attain the above object, this invention provides a manufacturing process of a stainless steel product by nitrogen absorption treatment, characterized by bringing a bulk product of ferritic stainless steel, which is made by melting, forming and machining into a desired shape, into contact with an inert gas containing nitrogen at or above 800°C to austenitize the product completely.

This invention also provides a stainless steel product characterized by having a completely austenitic structure formed by adding nitrogen through contact with an inert gas containing nitrogen to a bulk product of ferritic stainless steel which is made by melting, forming and machining into a desired shape.

The manufacturing process of a stainless steel product by nitrogen absorption treatment according to this invention and the stainless steel product thereby obtained will now be described in further detail with reference to examples.

Best Mode of Carrying Out the Invention

According to the method of this invention of manufacturing a stainless steel product by nitrogen absorption treatment, a bulk product of ferritic stainless steel made by melting, forming and machining into a desired shape is brought into contact with an inert gas containing nitrogen at or above 800°C so as to austenitize completely. A technique of bringing a bulk product having a desired shape into contact with an inert gas containing nitrogen at or above 800°C belongs to a nitrogen absorption treatment classified as a solid-phase absorption method. Nitrogen is added to the whole product by heating it to or above 800℃ in an inert gas atmosphere containing nitrogen. The method of this invention of manufacturing a stainless steel product by nitrogen absorption treatment makes it possible to obtain a product having a desired shape easily, since the product to which nitrogen is added is made of a ferritic stainless steel which is easier to work than austenitic stainless steel. The scale of equipment in the powder metallurgy method, limits to shaping and mechanical reliability of products is dissolved.

The stainless steel product of this invention which can be obtained as described is completely austenitized. Therefore, the stainless steel product of this invention is outstanding in both corrosion resistance and strength and is advantageously an inexpensive product, since its cost of processing is low, even if it has a complicated shape. The addition of at least about 0.5% by mass of nitrogen to a bulk product of ferritic stainless steel is sufficient for achieving the results as mentioned above.